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ABSTRACT

An experiment using an analysis of the distinctive features of lower case letters of the English alphabet to predict high- and low-confusible alternates for each letter was reported. Ten disadvantaged 5-year-old Negro children served as their own controls, circling in booklets the letters seen after a 1-second presentation by memory drum. The memory drum tapes used five random orders and presented each letter twice. The letters appeared in the response booklets once with high-confusible alternates and once with low-confusible alternates. Mean errors for the high-confusible condition equaled 7.7, for the low-confusible condition 2.1, significant by t test at the .01 level. The concepts most frequently involved in errors were (1) location in space (b - p, d - q, f -t) and (d - b, p - q) and (2) vertical extension of a letter part (d - a, q - a, n - h). Letter pairs with the lowest percentage of distinctive features were those most frequently confused. Tables, references, and an appendix are included. (Author/WB)

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THE PSYCHOLOGICAL REALITY OF THE APPARENT PERCEPTUAL DIMENSIONS OF THE ALPHABET

Barbara Redalia

The evidence regarding the value of perceptual development programs for kindergarten children's reading readiness is still contradictory. It may be that kindergarten children would be better served by inclusion in their curriculum of materials more directly related to reading, writing, and arithmetic than are those of the typical perceptual development program.

If we knew the dimensions along which children must learn to discriminate in order to learn the letters of the alphabet, and could indicate to children the critical distinctive features, then there would be a basis for developing a perceptual readiness program appropriate to the needs of kindergarten children, because it would be preparation for learning to read.

The purpose of this experiment is to investigate the perceptual attributes or dimensions by which the lower case letters of the alphabet may be distinguished by children learning to read. Proceeding from (a) a verbal description of each letter, to (b) a comparison of each letter with every other letter; an index (c) called "the % distinctive features" for letter pairs is obtained and computed for all possible comparisons of lower case letter pairs. The "% distinctive

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features" for letter pairs is then used to develop a set of high-confusible alternates and a set of low-confusible alternates for each letter of the alphabet. If the apparent dimensions have psychological reality for young children, they should make significantly more errors when circling letters which occur in a context of high-confusible alternates than when circling letters which occur in a context of low-confusible alternates.

There are two theory dilemmas to which the present research has relevance. The first dilemma, more apparent than real, stems from what may be a misinterpretation of the Piaget notion of schema as being a static concept. In this regard, Flavell (1963) points out the dynamic character of schemas, that to Piaget "differentiation has the consequence of dividing the originally global schema into several new schemas, each with a sharper, more discriminating focus on reality." ". . . it is characteristic of schemas not only to undergo individual changes of this kind but also to form ever more complex and interlocking relationships with other schemas."

Viewed as a <u>static</u> neural pattern (Gibson, 1963a) the notion of schema is not very consistent with accumulating evidence (Caviness, 1962) that mere visual-tactual associative pairing of stimuli, <u>without</u> differential, feature for feature comparisons among stimuli does not enhance young subjects ability to discriminate the stimuli in a visual identification test. If a schema (static concept) exists as a neural pattern

which becomes increasingly clearer from repeated exposure one would expect such exposure to enhance Ss' ability to discriminate among the stimuli. The results of the Caviness experiment, however, are consistent with a dynamic notion of schema, as described above by Flavell. It might be said that as distinctive features for discriminating among stimuli, for example, the letters of the alphabet, are attended to, the originally global schema becomes differentiated into new schemas for individual letters, each with a sharper, more discriminating focus on reality. The differences between the Piaget and Gibson theories of what is learned may be more a matter of emphasis rather than of essential incompatibility, as well as a misinterpretation of Piaget's concept.

The second theoretical dilemma concerns the question of whether the haptic (tactile) mode of perception is actually prior to the visual. Because I was urged by an adherent of this point of view to use the haptic mode of testing letter knowledge in four-year olds, that is, to give them three-dimensional models of graphic symbols to discriminate, as a task more appropriate to their kinaesthetic stage of development, it is necessary to justify a negative decision by analyzing some recent work bearing on this question.

Gibson describes (1963a) an experiment of Leibowitz, Waskow, Loeffler and Glaser which demonstrated that mental defectives of the same mental age as normal five-year olds show an increased tendency toward shape constancy when matching a series of ellipses

to a circle shown at seven different angles of inclination. More intelligent subjects tended to produce a geometric match. This is considered to be evidence that the mentally retarded have difficulty with visual discrimination problems. Next she cites an experiment of Piaget and Inhelder on the development of haptic perception in which children were presented with familiar objects and card-board cut-outs behind a screen and their hand movements observed and ability to identify the three-dimensional object or cut-out noted. From age 3½ to 4 the child could identify familiar objects but his tactile exploration was global and relatively passive. Between ages 4 and 6 the child could identify straight lines and curves, but could not differentiate <u>within</u> these groups. Toward the end of this period he becomes able to differentiate by attention to angles and dimensions. The child over six years old typically explores tactile stimuli methodically, and is able to distinguish among complex forms, stars, crosses, etc. Each of the above capability levels in development of the haptic mode is reached at an earlier age in the visual mode.

Gibson cites further (1963a) a series of experiments described to her by Zinchenko (personal communication from the Soviet Union) in which he directly compared the ability of children ranging in age from three to six years to discriminate two-dimensional forms presented visually with their ability to discriminate these objects haptically. The child was to view a stimulus for ten seconds and then select it from a group of three. Eye movements and errors were recorded. The three-

year olds made errors 50% of the time, and the five year olds made no errors. The eye movements of children from age three to four did not follow around the contours, but movements were saccadic and within the figure. Eye movements of children from age four to five were related to contour and only similar figures were confused. From age five on the eye movements followed around contours, pausing on distinctive features.

When these same figures were presented tactually to the children the three-year olds were unable to identify the stimuli, and the percentage of error decreased from 73% for four to five year olds to 23% for six and seven year olds. Hand movements were slow and clumsy in four year olds, and they did not trace the contour of the figure. In older children contour tracing became expert, with one finger dominating, and salient features used as "cues." When this direct comparison of the development of the haptic with the visual mode indicates the haptic to be consistently so much later in maturing, how then can we still maintain that touch provides the primitive basis for form perception? Even when a child explores a figure tactually, hands behind a screen, he is better able to identify it on a visual test than on a tactile test. A possible resolution to this problem may lie in the idea that young childrenIs capabilities for making visual and tactile discriminations are both inadequate and they thus feel compelled to use both modes as long as the inadequacy persists.

Gibson next cites her experiment in crossmodal transfer

comparing ability of retarded and normal children to identify unfamiliar letters of the Greek and Russian alphabet after either tactually or visually exploring them. The mentally retarded children, of the same mental age (5.4 years) as the normal children but with a chronological age of twelve years, were impaired in their visual discrimination but significantly better than normals of the same mental age in their tactual discrimination. The need for an additional control group of normal children twelve years old was noted.

The notion that the haptic mode is prior to the visual may originate, thus, in studies of the mentally deficient who are more severely handicapped visually than haptically (and considered to be at an earlier stage of development) and may also be founded in the difficulty subjects encounter in making discriminations within one dimension, compared to the ease of making discriminations among stimuli presented in a multi-dimensional manner. Miller and Nicely (1955) concluded that sets of stimuli which subjects are required to discriminate should be presented along as many dimensions as possible, decreasing the number of distinctions which Ss must make on a single dimension. Because of a limited capacity to process information input which varies in only one dimension (about 2½ bits, on the average) it is easier for subjects to make binary distinctions along a number of simultaneously occurring dimensions than it is to make absolute judgments among several alternatives along one dimension. Thus it is reasonable to suppose that the

reason children discriminate physical objects more easily than cut-outs and cut-outs more easily than painted shapes is not because the haptic mode is prior to the visual, but because the number of dimensions presented is greater in the physical object than in the cut-out, and greater in the cut-out than in the painted representation of it.

The experimenter agreed to seriously consider the testing of letter knowledge by use of physical three-dimensional objects and the above argument represents the major part of this consideration. In addition, it should be noted that for a measure to be predictive of reading achievement (an eventual goal) the conditions of the measure should be similar to the conditions of the criterion test, and measuring the stimuli to be discriminated in the visual mode would therefore seem to be desirable from this point of view, although for maximum learning efficiency stimuli should be presented in a multi-dimensional, multi-modal manner.

Why Should Children Learn Letters?

In the year 1958 a group of studies was published which demonstrated what many may have felt they knew on the basis of personal experience or intuitively, that children derive great benefit from knowing letter names and sounds when they are learning to read. These studies (Durrell, Gavel, Linehan, Nicholson, & Olson, 1958) have shown that the ability to identify lower case letters of the alphabet and to give letter sounds when the visual stimulus is presented are excellent predictors of First Grade reading success. That this is so has also been borne out in the more recent First Grade reading studies (Bond, 1967).

The study of Eleanor Linehan demonstrated experimentally that teaching letter names and sounds early in First Grade enhances reading achievement.

If it is desirable for children to be "learning letters" in kindergarten or from the beginning of First Grade, just what do we mean by "learning letters" and what are the prerequisites for such learning? A study of the background abilities of children as related to their reading success in First Grade (Nicholson, 1958) distinguishes operationally among the types of learning of letters by testing letter knowledge in the following ways, ranged in order of increasing difficulty.

1. Matching letters directly

O T O H D C

The child is told to find another letter like the one in the left hand box and to circle it. This type of test allows the child to directly compare the stimuli feature for feature; he need not rely upon previous experience of the letter, nor need he know the letter name. Memory influence is minimal.

2. Identifying letters shown

A letter is shown on a card for five seconds, then covered and the child directed to find it among five letters in a multiple choice situation. The child is thus dependent upon his short term memory of the stimulus presented, a more difficult task than the preceding one.

3. Identifying letters named

The examiner names a letter and the child is required to circle it in a multiple choice situation. He is thus depen-

dent upon past association between the letter named and the visual stimulus. That is, he must have learned them as paired associates at some time, and be able to recall this learning, to remember the letter heard, to recognize the letter, and to circle it.

4. Giving names of letters

Letters are printed on a large card, and the examiner points to each letter and asks the child to tell its name. This task was much more difficult than the preceding task, possibly because the child must choose from among all the letter names he remembers than from among only five possible multiple choices.

5. Writing letters from dictation

Ability to write letters from dictation is tested by giving aloud the name of the letter and asking the child to write or print it on the line. Either upper or lower case form is considered acceptable. For this task the child must have all of the capabilities of the previous tasks plus some experience in producing a facsimile of the letter itself.

6. Giving sounds of letters

Ability to give sounds of letters is tested individually by presenting letters on a large card and asking the child to tell the corresponding sounds. This task was the most difficult for the first grade children sampled. Only 3% could give sounds of 20 or more capital letters. The median score was 3.88, with a standard deviation of 5.66.

This somewhat detailed description of testing the various types of letter knowledge has been included to illustrate the

complexity of the learning which does take place and to give some indication of the ways in which the method selected for testing letter learning may influence the score.

What Dimensions Must Children Learn to Discriminate?

Significant work has been done in an analysis of the dimensions of upper case letters of the alphabet by Eleanor Gibson (1963b), who first drew up a feature chart for capital letters and obtained a confusion matrix for pre-reading children, comparing their errors in a task similar to that described in Number 2, identifying letters shown, only with the standard presented for one second, not five, and with six multiple choice alternatives. She found evidence to support the hypotheses that the following dimensions offer critical features for discrimination among capital letters.

1. Vertical (line)
2. Horizontal
3. Straight
4. Curved
5. Oblique /,\

Some other "gestalt type" attributes she tested were not confirmed, but her results, all told, were sufficient to warrant further investigation of the proposition that there <u>are</u> critical features by which children learn to distinguish letters. Twelve out of 26 Spearman rank order correlations were significant between the "% feature difference" for a letter pair and the number of confusions found between the letters of that pair.

The expected number of confusions for a given letter pair was controlled by random selection of letters in the multiple choice group, random order of presentation of the standards, and balanced occurrence of the correct choice in all 6 positions, left to right. Every letter thus had an equal opportunity to be mistaken for every other letter.

A prior experiment studying the discrimination of artificial letter like forms (Gibson, 1963c) traced the development from age four to eight of the progressive ability to discriminate within and between such dimensions as change of close and break (O - C), rotations and reversals (M - W), perspective, and line to curve (V - U) transformations. The results of this experiment led Gibson to the interpretation that during years four to eight children <u>do</u> learn the critical features for differentiation among letters, starting basically from skills derived at differentiating physical objects, not all of which skills are appropriate for graphic differentiation. She suggests that their initial errors at age four were high for reversals and rotations because transformations of this type are not critical for differentiation of physical objects, which is the skill of young children closest to differentiating graphic stimuli. Learning that a chair is still a chair whether viewed from the left or the right is not very helpful to the child who is called upon to discriminate "d" from "b". By the age of eight these errors of rotation and reversal have dropped very low;

apparently during this time children have learned that these distinctions which are irrelevant for physical objects are critical for graphic stimuli.

Children's initial errors at age four were also high for changes of perspective, but remained high, even at age eight, for changes of perspective are not critical for differentiating either objects or graphic stimuli, and therefore, there has been little cause for the child to learn this skill in those early years. We might hypothesize that if perspective were a critical feature of an alphabet then children's ability to make such differentiations would be learned as the children acquired skill in reading their language.

These studies by Gibson, of the distinctive features by which children learn to discriminate upper case letters of the alphabet, utilize a confusion matrix, for which she gives credit to Jakobsen and Halle (1956), who used this technique to study distinctive features of phonemes. Jakobsen and Halle, and Miller and Nicely have both used this method of analysis and have found information theory useful in the elucidation of the dimensions present in the sound system. The notion that the number of binary, yes-no, questions represents a useful measure of the amount of information in a stimulus is an intriguing and instructive idea with which to work. Evenso, it seemed that a more economical description of the dimensions present in a pair of letter stimuli to be differentiated could be based upon a consideration of the relevance of features for a particular

discrimination as described by Roger Brown (1958). In his discussion of this subject he points out, for example, that some attributes are "noisy" for a particular discrimination. One does not discriminate among various models of Chevrolet by the presence of four wheels in one model and not in another, but by the features which are relevant, that is, present in some, and absent in others, or arranged in a distinctive way, such as chrome distribution, etc. Similarly, one does not discriminate between the letters "q" and "o" on the basis of the difference between a straight line and a curved line, but on the basis of the vertical tangent in the letter "q." The superiority of an approach which considers relevance for this particular task to an information analysis lies both in the elimination of redundant questions from description of the letter pairs, and in the fact that not all attributes are economically described in a binary fashion. When one letter has a tangent "q" and one does not "o", the child need only be able to discriminate between presence and absence of the tangent, for that particular discrimination, as the left-right distinction is not relevant for this particular letter pair, at least on a logical basis to an adult.

The informational analysis approach, on the other hand, would lead one to specify each letter exactly and would require not only a binary question for presence-absence of the tangent, but another binary question for right-left location of the tangent. The child need not be able to specify exactly and completely the two letters in order to discriminate between them, as he essen-

tially does learn to do later on by the time he can print letters from dictation, the most advanced of the letter learning tasks described earlier.

A Three-Stage Problem

This investigation of the perceptual dimensions of the alphabet breaks down into three distinct phases, an analysis of the critical features and dimensions of the lowercase letters of the alphabet, the testing of the psychological reality of the hypothesized dimensions, and a controlled experiment to ascertain the effect on first grade reading achievement of teaching children the alphabet by means of teaching them the dimensions along which letters vary, and the distinctive features by which they may be discriminated.

Phase 1, the analysis of the critical features and dimensions of the lower case letters of the alphabet has been essentially completed. The appendix includes a complete listing of the 325 possible combinations of the 26 letters of the alphabet, together with the derivation of the "% distinctive features" for each letter combination. This information is summarized in Table 1.

Phase 2, the testing of the psychological reality of these dimensions, can be approached directly by presenting simultaneously pairs of letters which differ in one distinctive feature and asking children to describe how these two shapes are different, and recording their responses. Such a straightforward approach should not be over looked because it offers

information which cannot be obtained in any other way. The language of children's descriptions of the differences they see will differ from that of the adult, no doubt, but if our distinctive features are actually used by children there should be some evidence of this in their responses, and we may gain some new insights into their ways of conceptualizing distinctive differences which would not occur to us as adults.

A second and experimental approach to the question of the psychological reality of the dimensions or distinctive features would be offered by an experiment in which children's confusions in identifying letters shown are correlated with the "% distinctive features" for that letter pair. One would hypothesize a negative relationship between these two measures. That is, letter pairs with a low "% distinctive features" should provide many confusion errors.

Two different methods were used by Gibson for presenting visual stimuli to children and securing a confusion matrix of their discrimination errors. The advantages and disadvantages of each method have been considered and a compromise selected. In the experiment using artificial letter-like forms (Gibson, 1963c) young children were shown a stimulus on a card for one second, and the card was then concealed, and the children were given three seconds to find and indicate the matching letter in a multiple choice situation. The second alternative method of presentation involves the use of a memory drum on which the letters are printed by a sign typewriter on adding machine tape

so that the standard appears for one second followed by the six multiple choice letters from which the child selects the match for the standard. In each method an equal opportunity for each letter to be mistaken for each other letter must be assured by randomization of the order of the standards, randomization of the multiple choice alternatives, and balancing of the position of the correct match among the alternatives. The first alternative technique has the advantage of requiring no memory drum, although a table or tables with built in trays or ledges for the cards must be prepared. The first technique suffers the disadvantage of inadequately controlling the stimulus presentation time, which may be rather critical in this experiment, and offers the opportunity to children of mixing up the cards, which must be rather tempting to them and annoying to the experimenter. The second technique, using the memory drum, offers the advantage of close control of stimulus presentation time, coupled with the disadvantage of requiring the experimenter to record the Ss' errors as the subject points to the match with the stylus. The experiment to be described herein used a combination of these two methods, with the memory drum for stimulus presentation only, not for the multiple choice assortment, coupled with a booklet which the subject could actually mark after seeing the stimulus on the drum, each assortment of letters being on a separate page of the booklet, and each booklet keyed to correspond to a particular series of stimuli on the drum. This approach seemed to

offer a worthwhile combination of advantages, accurate control of the stimulus interval, and the subject records his own responses so that there is no ambiguity in ascertaining which letter he is pointing to.

Gibson found, in her experiment with capital letters, that in order to secure sufficient errors for analysis it was necessary to use as subjects all 87 four-year olds from 5 nursery schools, replacing as subjects those children making no errors with new subjects. As an extra measure designed to gain maximum information from a small number of subjects she devised a predicted high confusion list and a predicted low confusion list, and from the administration of both these lists to each of 20 subjects she was able to obtain further evidence bearing on the theory of distinctive features in terms of the significance of the difference between the mean number of confusions for the two lists. While it might be desirable to have a potential sample of 100 four-year olds for an experiment in which each letter occurs equally often as an alternate with every other letter, it seemed that for a pilot study it would be more economical of time and effort to limit the study to 10 subjects who would receive both high confusible and low confusible alternates, thus serving as their own controls for individual difference variables.

Phase 2

The purpose of this experiment is to investigate the perceptual attributes or dimensions by which lower case letters of the alphabet may be distinguished by children learning to read. Proceeding from (a) a verbal description of each letter, to (b) a comparison of each letter with every other letter; an index (c) called the "% distinctive features" is obtained and computed for all possible comparisons of lower case letter pairs. The "% distinctive features" is defined as the ratio of the number of features possessed by one letter but not by both, to the total number of features in both letters. This index varies from nearly zero to + 1, with small values representing letter pairs which have many common features with relation to their total number of features. Values close to one represent letter pairs which have few common features, and the value 1 represents no common features. Tables 1 through 3 represent a chronological sequence in the development of this index. Table 1 lists the letters of the alphabet, described verbally. Table 2 lists the features derived from this description, and Table 3 gives the % distinctive features for each letter compared with every other letter. The Appendix contains the 325 letter feature comparisons which are summarized in Table 3.

For every letter of the alphabet one can find in Table 3 the four other letters of the alphabet with the lowest "% distinctive features and the four letters of the alphabet with the highest "% distinctive features". This is the manner in which the predicted high-confusible alternates and the predicted low-confusible alternates were selected.

Hypotheses

1. If the attempt to identify distinctive features of letters and to determine the "% distinctive features for all possible letter pairs has psychological reality for children aged four to five there should be a significantly greater number of errors in identifying letters in a context of highly confusible alternatives with many common features than from among low confusible alternatives with a high "% distinctive features."

2. Dimensional differences which are not critical for distinguishing physical objects, e. g. left-right, and top-bottom, should evidence more confusions than dimensional differences which are relevant to distinctions which the child has learned to make among physical objects, e. g. open-closed, doubling, crossbar, extent, etc.

This prediction is based upon both rational considerations and upon the findings of Eleanor Gibson in her work with capital letters and with artificial letters. The frequency of such confusion errors for each dimensional difference should be compared to the total number of opportunities for such errors to occur. This amounts to an hypothesis to the effect that the ratio of errors/ opportunity for errors will be greater for those dimensions in which distinctions are not critical for physical objects.

3. For each letter of the alphabet the letter most frequently confused should be that one with the smallest "% distinctive features.

Procedures

Experimental Variable

For each letter of the alphabet two sets of multiple choice alternatives were prepared, a high-confusible list and a low-confusible list. The high-confusible alternatives for a letter are those letters which have the smallest "% distinctive features" (see Table 3). The low confusible alternatives are those letters which have the highest "% distinctive features." This list is presented as Table 4.

Experimental Materials

Each letter of the alphabet is presented twice to each subject on a memory drum tape, and he is instructed to circle the letter he has seen on the page of his response booklet. On one presentation of the standard the page contains four high-confusible alternatives and on one presentation the page contains low-confusible alternatives. The difference between the subjects' mean number of errors with high confusible alternatives and number of errors with low confusible alternatives is the dependent variable we measure to test this hypothesis.

Order Effects

Five different memory drum tapes are prepared on which the letters of the alphabet occur in five different random orders, to control for practice effects during the course of the experiment. Five different 52 page booklets are prepared with the pages ordered to correspond to the order of the letters occurring on the five tapes.

The correct choice or standard occurs equally often at each of the five left to right positions in the response booklet in

order to control for the tendency to a position response set.

Practice Materials

In order to further control practice effects a sixth abbreviated memory drum tape was prepared containing 5 numbers and a corresponding 5 page booklet was prepared to demonstrate to each subject the manner in which the experiment was to be done and to attempt to ensure cooperative subjects. This practice tape was used with all subjects.

Equipment

The letters presented to the subjects, both on the memory drum tapes and in their corresponding booklets were produced with an IBM electric primary typewriter with one modification. The letter "o" was modified by addition of a tangent on the right to produce a primary letter "ɑ" rather than "a." The typing was done directly on the tapes but was xeroxed for the booklets.

The memory drum used was Lafayette Instrument Co, Model #303A, capable of varying the presentation interval from ½ to 4 sec. and of being stopped between presentations to allow S to record his response.

Instructions

Following the subject's successful completion of the practice set of materials the experimenter told him that he would like to change the tape now from one with numbers to one with letters, that he should watch the little window and then circle the letter he saw on the page of his booklet. The experimenter turned the pages for the subject and turned the drum off after each letter to allow subjects freedom to concentrate on the experimental task and ensure that the subject was always on the

correct page. Frequent use was made of the words "Ready?" and "Here it comes" and of finger pointing to the window to ensure the child's attention being focused there for each presentation. The drum cannot be reversed in case a letter is missed.

Subjects and Environment

The subjects for this study were 10 Negro children enrolled in the Pre-School of Cole Elementary School in Oakland, California. Their socio-economic status was low, a pre-requisite for this state-supported program. Their average age was 59.7 months, or nearly five years as of June 1, 1969. All will be five years old by December 1, 1969. The subjects had all been in attendance for about 1½ years at this school. They have a small sight-reading vocabulary and can write a few letters, the result of energetic efforts of their teacher to prepare them for school success.

From the class of 15 children 5 were eliminated from the study for the following reasons:

1. One child balked and did not wish to complete when about 2/3 of the way through the study.
2. One child was Indian rather than Negro.
3. One child was a late entry into the class, very immature, and the teacher did not advise working with him.
4. One child had just completed the practice test on the last day of testing when his babysitter called for him early and he had to leave school.

5. One child was randomly omitted to keep the number of subjects at a multiple of 5, since there were 5 tapes, 5 booklets, and 5 random orders.

The experiment was conducted individually at a low table with child and experimenter seated side by side in a large empty classroom of the elementary school where the Pre-School is located. The experiment required approximately 20 minutes per child, depending upon the speed and attention of the child and the amount of supportive conversation required. There were no significant interruptions during any of the administrations.

Results

Total Errors

Table 5 is a Summary of Errors by Subjects. There were 77 errors in the high-confusible condition and 21 errors in the low-confusible condition, and 6 errors of omission, due usually to the subject not attending when the letter appeared.

Hypothesis 1

A distribution of difference scores is obtained by subtracting the subjects' low-confusible errors from their high-confusible errors to measure the difference for each subject between identifying letters from among high-confusible alternates and identifying letters from among low-confusible alternates. The mean difference was 5.6, that is, the average subject made 5.6 more errors in the high confusible condition than in the low-confusible condition. This is supportive of

the hypothesis that there should be a significantly greater number of errors in identifying letters in a context of high-confusible alternates with many common features than in a context of low-confusible alternates with a high "% distinctive features."

Hypothesis 2

For each high confusible error the assumption is made that there is at least one concept or attribute involved (which the subject has missed). Table 6 lists the "concepts involved in errors" ranked in order of the frequency of error together with examples of the letter pairs involving each concept. It should be pointed out that this information does not constitute an exact confirmation of the hypothesis since these errors are not stated as ratios to the opportunity for those errors to occur. Still it is true that the three greatest sources of error within the experiment were the concepts top-bottom, extends, and left-right. The first and third of these concepts are not critical for distinguishing among physical objects. If each letter of the alphabet had occurred equally often as an alternate with each standard on tape it would have been more practical to test this hypothesis exactly, for one could then assume an equal probability of error. Unfortunately many more subjects would have been required to obtain enough errors for analysis. An actual test of this hypothesis thus awaits further analysis or another experiment.

Hypothesis 3

If for each letter the letter most frequently confused is that one with the smallest "% distinctive features" a tally of the confusions for each letter of the alphabet should demonstrate this relationship. In Table 7 one can see that for fourteen of the 16 letters having enough errors to analyze the letter most frequently confused was the one with the smallest "% distinctive features" as predicted by the analysis. The two cases when this did not occur were the letters "q" and "u."

The prediction for "q" was based upon a "q" with a curved segment at the bottom, unlike the type actually used on the tapes and booklets. This error in predictions may have accounted for this discrepancy.

The prediction for "u" may however be a genuine exception to the rule and may indicate that the distinction "top-bottom" is more difficult to learn and to make than the distinction "open-closed." Such a difference, appealing to gestalt psychologists, may have outweighed the fact that the tangents are on opposite sides in "u" and in "n," whereas in "q" and in "u" they are on the same side.

Table 1

Verbal Descriptions of the Letters of the Alphabet

a Circle, closed, right tangent

b Circle, closed, left tangent, extends top

c Circle, open right

d Circle, closed, right tangent, extends top

e Circle, open right, segment within

f Straight line, vertical, extends top, crossbar, curved segment top right

g Circle, right tangent, extends bottom, curved segment bottom left

h Circle, open bottom, left tangent, extends above

i. Straight line, vertical, dotted

j Straight line, vertical, dotted, extends bottom, curved segment bottom left

k Straight line, extends top, slanting segments to right

l Straight line, vertical, extends top

m Circle, open bottom, doubled, left tangent

n Circle, open bottom, left tangent

o Circle, closed

p Circle, left tangent, extends bottom

q Circle, right tangent, extends bottom, curved segment bottom right

r Straight line, vertical, curved segment to right

s Circle, doubled, open right top, open left bottom (alternation)

t Straight line, vertical, crossbar, curved segment bottom right

u Circle, open top, right tangent

v Slanted lines, alternating horizontally

w Slanted lines, alternating horizontally, doubled

x Slanted lines, crossing

y Slanted lines, alternating horizontally, extends bottom

z Horizontal lines, alternating vertically, open left top, right bottom.

Table 2

Apparent Features of Letters of the Alphabet

Line Characteristics	Circle Characteristics
1. straight; (l)	1. closed; (o)
2. curved; (r)	2. open; (c)
3. vertical; (l)	3. right-left; (c)
4. horizontal; (z)	4. top-bottom; (u, n)
5. slanted, (k)	5. tangent; (d)
6. extends top; (h)	6. segment within; (e)
7. extends bottom; (p)	7. doubling; (m)
8. relative position to right	8. alternation; (s)
9. relative position to left; (b)	
10. curved segment right; (f)	
11. curved segment left; (g)	
12. alternation, vertical; (s)	
13. alternation, horizontal; (v)	
14. doubling; (w)	
15. crossing; (x)	
16. dotting; (i)	
17. junction; (k)	

Table 3

% Distinctive Features of Letter Pairs

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
a		33	60	14	67	*	25	56	*	67	60	50	56	50	20	33	14	60	67	71	33	*	*	*	*	*
b			67	20	67	50	45	20	67	75	43	33	40	33	33	20	45	67	71	50	56	*	*	*	*	*
c				67	14	*	71	50	*	*	*	*	50	43	50	67	71	*	33	*	43	*	*	*	*	*
d					71	50	45	40	67	75	60	33	75	71	33	40	27	67	67	50	43	*	*	*	*	*
e						*	75	56	*	*	*	*	50	43	60	71	75	*	43	*	50	*	*	*	*	*
f							75	67	67	60	43	33	75	71	*	75	56	33	*	25	71	*	*	60	71	*
g								64	71	33	71	67	78	75	43	27	17	71	78	71	60	*	*	*	*	*
h									67	75	43	33	25	14	67	40	64	67	60	50	45	*	*	*	*	*
i										33	50	50	67	60	*	67	71	50	*	60	60	*	*	*	*	*
j											71	67	75	71	*	50	45	67	*	60	71	*	*	*	*	*
k												20	71	67	*	71	75	60	*	60	67	60	67	33	67	50
l													67	60	*	67	71	50	*	60	60	*	*	*	*	*
m														14	67	50	64	67	60	71	45	*	67	*	*	*
n															60	43	60	60	56	71	40	*	*	*	*	*
o																33	43	*	67	*	60	*	*	*	*	*
p																	33	67	71	75	56	*	*	*	67	*
q																		71	75	78	50	*	*	*	71	*
r																			67	60	*	*	*	*	*	*
s																				*	56	*	*	*	*	67
t																					71	*	*	50	*	67
u																						*	*	*	*	*
v																							25	60	20	50
w																								50	50	60
x																									50	60
y																										60
z																										

* 100% Distinctive Features

Table 4

Multiple Choices Used

High Confusible						Low Confusible					
1.	d	g	(a)	q	b	27.	(q)	y	v	w	x
2.	h	p	d	(b)	a	28.	v	(b)	x	z	w
3.	n	u	e	s	(c)	29.	w	v	(c)	y	x
4.	(d)	a	b	q	l	30.	z	w	x	(d)	v
5.	u	(e)	s	n	c	31.	v	y	w	x	(e)
6.	r	l	(f)	k	t	32.	(f)	e	s	a	c
7.	j	a	q	(g)	p	33.	z	(g)	w	x	v
8.	b	l	n	m	(h)	34.	y	x	(h)	w	v
9.	(i)	p	n	m	l	35.	a	c	e	(i)	o
10.	p	(j)	q	i	g	36.	s	w	x	o	(j)
11.	f	b	(k)	h	x	37.	(k)	m	q	s	c
12.	d	b	f	(l)	h	38.	s	(l)	o	e	v
13.	u	h	n	b	(m)	39.	v	y	(m)	x	z
14.	(n)	m	b	u	h	40.	x	w	v	(n)	y
15.	q	(o)	b	d	p	41.	t	l	f	j	(o)
16.	n	b	(p)	g	a	42.	(p)	z	v	x	w
17.	p	d	g	(q)	d	43.	v	(q)	x	w	z
18.	q	i	l	f	(r)	44.	e	v	(r)	w	c
19.	(s)	n	c	e	u	45.	i	l	f	(s)	k
20.	f	(t)	x	h	b	46.	s	o	c	e	(t)
21.	d	d	(u)	c	n	47.	(u)	r	x	w	z
22.	w	z	y	(v)	x	48.	g	(v)	o	d	a
23.	v	y	x	z	(w)	49.	b	e	(w)	r	h
24.	(x)	k	y	w	f	50.	g	q	c	(x)	i
25.	v	(y)	x	w	z	51.	d	n	j	b	(y)
26.	y	w	(z)	x	k	52.	(z)	c	e	n	i

Table 5

Summary of Errors by Subjects

Subject	Order Number	Sex	Errors			Omit	Total
			High Con.	Low Con.	Diff.		
1.	2	F	4	0	+4	1	5
2.	4	M	7	1	+6	0	8
3.	3	M	7	0	+7	0	7
4.	1	F	8	5	+3	0	13
5.	5	M	6	3	+3	3	12
6.	5	M	11	4	+7	0	15
7.	3	M	10	3	+7	0	13
8.	2	M	10	2	+8	2	14
9.	4	M	8	2	+6	0	10
10.	1	F	6	1	+5	0	7
			77	21	$\Sigma D = 56$	6	
					$\bar{X}_D = 5.6$		

Table 6

Concepts Involved in Errors

Ranked in Order of Frequency of High-Confusible Errors

Concept	Frequency	Type of Concept
1. Top-Bottom; (b-p, d-q, f-t)	25	Location in Space
2. Extends; (d-a, q-a, n-h)	21	Magnitude
3. Left-Right; (d-b, p-q)	12	Location in Space
4. Crossbar, crossing; (x-v)	7	Presence-absence
5. Open-Closed; (d-u, b-h, q-u)	5	Presence-absence
6. Open top - Open right (u-c)	4	Location in Space
7. Curved Segment; (a-g, q-g)	4	Presence-absence
8. Vertical-Horizontal; (h-k)	3	Location in Space
9. Doubling; (w-v, m-n)	3	Number
10. Tangent; (c-u, h-c)	3	Presence-absence
11. Segment within; (c-e, u-e)	3	Presance-absence
12. Straight-curved;(h-k)	1	Linearity
13. Circle; (d-l)	1	Presence-absence
14. Slanting segments (y-t)	1	Obliqueness

Table 7

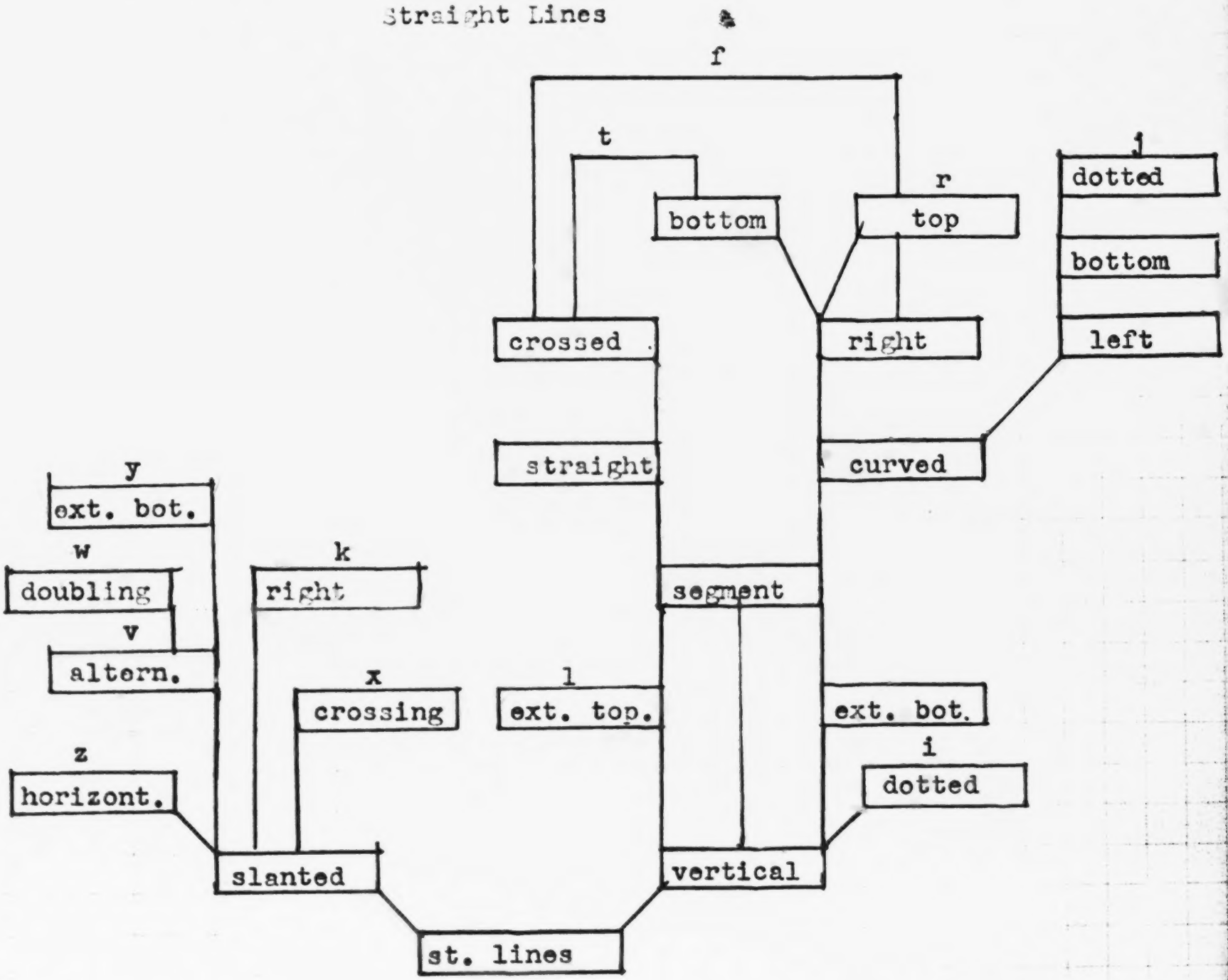
Comparison of Predicted and Obtained Confusion Errors

Letter	Smallest % Distinctive Features	Obtained Frequency of Errors
a	d = .14	6 d's, 1 g, 1 q, 1 u
b	p = .20	11 p's, 5 d's, k, h, m
c	e = .14	2 e's, 2 u's, h
d	a = .14	6 a's, 5 b's, 4 g's, u
e	c = .14	2 c's, u
f	t = .25	6 t's, 4 r's, l
g	q = .17	3 q's, a
h	n = .14	5 n's, b, k, c
k		h, b
l		f
m		b, u
n	h = .14	5 h's, 3 u's
p	b = .20	11 b's, 4 q's
q	d = .14	5 p's, 4 d's, 3 g's
r	f = .33	4 f's, a
t	f = .25	6 f's
u	o = .33	3 n's, 2 c's, e, d, m, a
v		w, x, y, z
w		v
x		y, v
y	z = .60	2 z's, x, v
z	y = .60	2 y's, v

Diagram 1

Relationships among Attributes of Lower Case Letters

Straight Lines

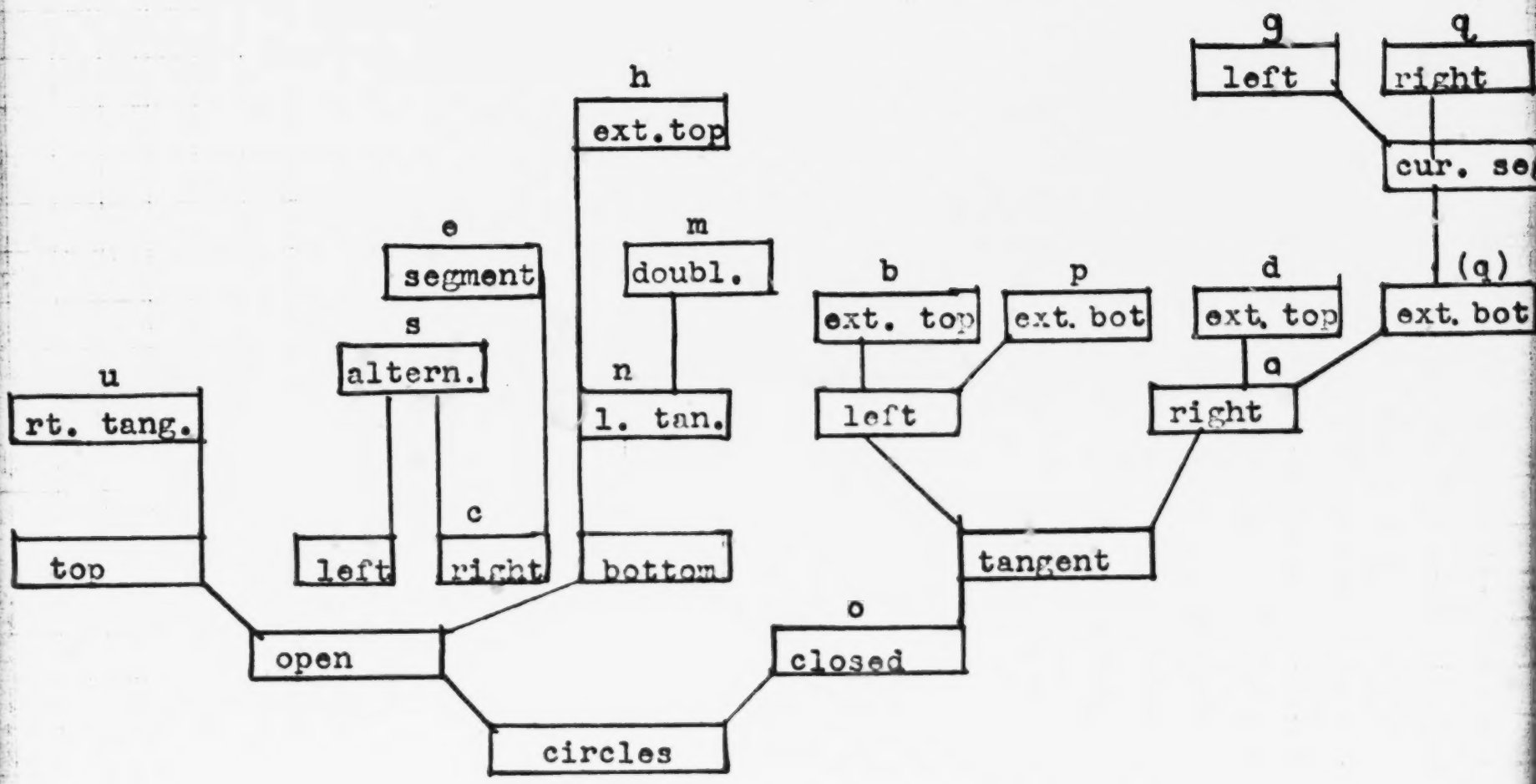


1.

Diagram 2

Relationships among Attributes of Lower Case Letters

Circles



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Appendix

Letter Pair	Common Features	Distinctive Features	%Distinctive
a + b	Circle, closed, tangent (6)	Rt. vs. left tangent, extends above (3)	3/9 = .333
a + c	Circle (2)	Closed vs. open, rt. tangent (3)	3/5 = .60
a + d	Circle, closed, rt. tangent (6)	Tangent extends above (1)	1/7 = .142
a + e	Circle (2)	Closed vs. open, rt. tangent, segment within (4)	4/6 = .667
a + f	None	All	1.00
a + g	Circle, closed, rt. tangent (6)	Extends below, curved segment (2)	2/8 = .25
a + h	Circle, tangent (4)	Closed vs. open, left vs. rt., extends above (5)	5/9 = .555
a + i	None	Circle, closed, rt. tangent, st. line dotted (5)	5/5 = 1.0
a + j	Vertical line (= tangent) (2)	(Basic shape), circle vs. line, dotted, curv. segment (4)	4/6 = .667
a + k	Vertical line (2)	(Basic shape) circle vs. line, slanted segments (3)	3/5 = .60
a + l	Vertical Line (2)	(Basic Shape) circle vs. line (2)	2/4 = .50

Letter Pair	Common Features	Distinctive Features	% Distinctive
a + m	Circle, tangent (4)	Closed vs. open, tangent rt. vs. left, doubling (5)	5/9 = .555
a + n	Circle, tangent (4)	Closed vs. open, tangent rt. vs. left (4)	4/8 = .500
q + o	Circle, closed (4)	Rt. tangent	1/5 = .200
a + p	Circle, closed, tangent (6)	Rt. vs. left tangent, extends below (3)	3/9 = .333
a + q	Circle, closed, tangent (6)	Extends below (1)	1/7 = .142
a + r	Vertical line (2)	(Basic shape) circle vs. line, curved segment (3)	3/5 = .60
a + s	Circle (basic shape) (2)	Closed vs. open, tangent, alternation (4)	4/6 = .667
a + t	Vertical line (2)	(Basic shape) circle vs. line, curved segment, crossbar, extends above (5)	5/7 = .714
a + u	Circle, tangent, right (4)	Closed vs. open (2)	2/6 = .333
a + v	None	All	1.000
a + w	None	All	1.00
a + x	None	All	1.00
a + y	None	All	1.00
a + z	None	All	1.00

Letter Pair	Common Features	Distinctive Features	% Distinctive
b + c	Circle (2)	Closed vs. open, left tangent, extends above (4)	4/6 = .667
b + d	Circle, closed, tangent, extends above (8)	Tangent on left vs. tangent on right	2/10= .20
b + e	Circle (2)	Closed vs. open, tangent, within segment (4)	4/6 =..667
b + f	Vertical line, extends above (4)	(Basic shape) circle vs. line, crossbar, curved segment	4/8 = .50
b + g	Circle, closed, tangent (6)	Tangent left vs. rt, extends above vs. below, with curv. segment (5)	5/11= .454
b + h	Circle, tangent, left, extends above (8)	Circle open vs. closed (2)	2/10= .20
b + i	Vertical line (= tangent) (2)	(Basic shape) circle vs. line, dotted, extends above (4)	4/6 = .667
b + j	Vertical line (2)	(Basic shape) circle vs. line, extends above vs. below, dotted, curved segment (6)	6/8 = .75

Letter Pair	Common Features	Distinctive Features	% Distinctive
b + k	Vertical line, extends above (4)	(Basic shape) circle vs. line, slanting segments to right (3)	3/7 = .428
b + l	Vertical line, extends above (4)	(Basic shape) circle vs. line (2)	2/6 = .333
b + m	Circle, tangent, left (6)	Closed vs. open, tangent extends above, doubling (4)	4/10= .40
b + n	Circle, tangent, left (6)	Closed vs. open, tangent extends above, (3)	3/9 = .333
b + o	Circle, closed (4)	Tangent on left, extends above (2)	2/6 = .333
b + p	Circle, closed, tangent, left (8)	Extends above vs. extends below (2)	2/10= .20
b + q	Circle, closed, tangent (6)	Tangent left vs. right, extends above vs. below, curv. segment (5)	5/11= .454
b + r	Vertical line (2)	(Basic shape) circle vs. line, extends above, curv. segment (4)	4/6 = .667

Letter Pair	Common Features	Distinctive Features	% Distinctive
b + s	Circle (2)	Closed vs. open, tangent, extends above, alternation (5)	5/7 = .714
b + t	Vertical line, extends above (4)	(Basic Shape) circle vs. line, crossbar, curved segment	4/8 = .50
b + u	Circle, tangent (4)	Tangent left vs. rt., extends above, open vs. closed	5/9 = .555
b + v	None	All	1.00
b + w	None	All	1.00
b + x	None	All	1.00
b + y	None	All	1.00
b + z	None	All	1.00
c + d	Circle (2)	Open vs. closed, rt. tangent, extends above (4)	4/6 = .667
c + e	Circle, open, right (6)	Segment within (1)	1/7 = .142
c + f	None	All	1.00
c + g	Circle (2)	Open vs. closed, tangent, extends below, curves to left (5)	5/7 = .714
c + h	Circle, open (4)	Open right, vs. open bottom, left tangent, extends above (4)	4/8 = .50

Letter Pair	Common Features	Distinctive Features	% Distinctive
c + i	None	All	1.00
c + j	None	All	1.00
c + k	None	All	1.00
c + l	None	All	1.00
c + m	Circle, open (4)	Open right vs. open bottom, left tangent, doubling (4)	4/8 = .50
c + n	Circle, open (4)	Open right vs. open bottom, left tangent (3)	3/7 = .428
c + o	Circle (2)	Open right vs. closed (2)	2/4 = .50
c + p	Circle (2)	Open right vs. closed, left tangent, extends below (4)	4/6 = .667
c + q	Circle (2)	Open right vs. closed, tangent, extends below, curv. segment (5)	5/7= .714
c + r	None	All	1.00
c + s	Circle, open rt. (4)	Alternation, open left bottom (2)	2/6 = .333
c + t	None	All	1.00
c + u	Circle, open (4)	Open top vs. open rt, right tangent	3/7 = .428

Letter Pair	Common Features	Distinctive Features	% Distinctive
c + v	None	All	1.00
c + w	None	All	1.00
c + x	None	All	1.00
c + y	None	All	1.00
c + z	None	All	1.00
d + e	Circle (2)	Closed vs. open, tangent, extends above, segment within (5)	5/7 = .714
d + f	Vertical line, extends above (4)	(Basic shape) circle vs. line, crossbar, curved segment (4)	4/8 = .500
d + g	Circle, closed, tangent (6)	Tangent rt. vs. tangent left, extends above vs. below, curv. segment (5)	5/11= .454
d + h	Circle, tangent, extends above (6)	Closed vs. open, left tangent vs. rt. (4)	4/10= .40
d + i	Vertical line (2)	(Basic shape) circle vs. line, extends above, dotted (4)	4/6 = .667
d + j	Vertical line (2)	(Basic shape) circle vs. line, extends above vs. below, curv. segment, dotted (6)	6/8 = .75

Letter Pair	Common Features	Distinctive Features	% Distinctive
d + k	Vertical line (2)	(Basic shape) circle vs. line, slanting segments to rt. (3)	3/5 = .60
d + l	Vertical line, extends above (4)	(Basic shape) circle vs. line	2/6 = .333
d + m	Circle (2)	Closed vs. open, doubling, tangent rt. vs. tangent left, extends above (6)	6/8 = .75
d + n	Circle (2)	Closed vs. open, left tangent vs. rt., extends above (5)	5/7 = .714
d + o	Circle, closed (4)	Right tangent, extends above (2)	2/6 = .333
d + p	Circle, closed, tangents extend (6)	Extends above vs. below, left vs. rt. (4)	4/10 = .40
d + q	Circle, closed, tangent, right (8)	Extends above vs, below, curv. segment to rt. (3)	3/11 = .272
d + r	Vertical line (2)	(Basic shape) circle vs. line, extends above, curv. segment (4)	4/6 = .667

Letter Pair	Common Features	Distinctive Features	% Distinctive
d + s	Circle (2)	Closed vs. open, tangent, alternation (4)	4/6 = .667
d + t	Vertical line, extends above (4)	(Basic shape) circle vs. line, crossbar, curv. segment (4)	4/8 = .50
d + u	Circle, right tangent (4)	Open vs. closed, tangent extends above	3/7 = .428
d + v	None	All	1.00
d + w	None	All	1.00
d + x	None	All	1.00
d + y	None	All	1.00
d + z	None	All	1.00
e + f	None	All	1.00
e + g	Circle (2)	Open vs. closed, tangent, extends below, curv. segment, segment within (6)	6/8 = .75
e + h	Circle, open (4)	Open right vs. open bottom, tangent, extends above, segment within (5)	5/9 = .555
e + i	None	All	1.00
e + j	None	All	1.00
e + k	None	All	1.00
e + l	None	All	1.00

Letter Pair	Common Features	Distinctive Features	% Distinctive
e + m	Circle, open (4)	Open right vs. open bottom, doubling, within segment (4)	4/8 = .50
e + n	Circle, open (4)	Open right vs. open bottom, segment within (3)	3/7 = .428
e + o	Circle (2)	Open vs. closed, segment within	3/5 = .60
e + p	Circle (2)	Open vs. closed, segment within, tangent, extends below (5)	5/7 = .714
e + q	Circle (2)	Open vs. closed, segment within, tangent, extends below, curved segment (6)	6/8 = .75
e + r	None	All	1.00
e + s	Circle, open on right	Alternation, segment within, open left bottom (3)	3/7 = .428
e + t	None	All	1.00
e + u	Circle, opem (4)	Open right, vs. open top, segment within, right tangent (4)	4/8 = .50

Letter Pair	Common Features	Distinctive Features	% Distinctive
e + v	None	All	1.00
e + w	None	All	1.00
e + x	None	All	1.00
e + y	None	All	1.00
e + z	None	All	1.00
f + g	Vertical line (2)	(Basic shape) circle vs. line, extends above vs. below, crossbar, curved segment (6)	6/8 = .75
f + h	Vertical line (2)	(Basic shape) circle vs. line, crossbar, curved segment (4)	4/6 = .667
f + i	Vertical line (2)	Crossbar, dotted, curved segment, extends above (4)	4/6 = .667
f + j	Vertical line, curved segment (4)	Crossbar, dotted, segment at top vs. at bottom, curved left vs. curv. right (6)	6/10 = .60
f + k	Vertical line, extends above (4)	Slanted segments, crossbar, curved segment	3/7 = .428
f + l	Vertical line, extends above (4)	Curved segment, crossbar (2)	2/6 = .333

Letter Pair	Common Features	Distinctive Features	% Distinctive
f + m	Vertical line (2)	(Basic shape) circle vs. line, extends above, curv. seg., doubling, crossbar (6)	6/8 = .75
f + n	Vertical line (2)	(Basic shape) circle vs. line, extends above, cross-bar, curved segment (5)	5/7 = .714
f + o	None	All	1.00
f + p	Vertical line (2)	(Basic shape) circle vs. line, extends above vs. below, crossbar, curved segment (6)	6/8 = .75
f + q	Vertical line, curv. segment to right (4)	(Basic shape) circle vs. line, crossbar, curv. segment at top vs. at bottom (5)	5/9 = .555
f + r	Vertical line, curv. segment at top (4)	Crossbar, extends above (2)	2/6 = .333
f + s	None	All	1.00
f + t	Vertical line, crossbar, curved segment (6)	Curved segment at top vs. curved segment at bottom (2)	2/8 = .25
f + u	Vertical line	(Basic shape) circle vs. line, crossbar, curv. segment, extends above,	5/7 = .714

Letter Pair	Common Features	Distinctive Features	% Distinctive
f + v	None	All	1.00
f + w	None	All	1.00
f + x	Crossing segments (2)	Slanting vs. vertical lines, curved segment at top (3)	3/5 = .60
f + y	Curved segments (2)	Slanting vs. vertical lines, curve at top vs. at bottom, crossbar (5)	5/7 = .714
f + z	None	All	1.00
g + h	Circle, tangent (4)	Closed vs. open, rt. tangent vs. left, extends above vs. below, curved segment (7)	7/11= .636
g + i	Vertical line (2)	(Basic shape) circle vs. line, dotted, extends below, curved segment (5)	5/7 = .714
g + j	Vertical line, extends below, curved segment to left (6)	(Basic shape) circle vs. line, dotted (3)	3/9 = .333
g + k	Vertical line (2)	(Basic shape) circle vs. line, slanting segments, extends below, curved segment (5)	5/7 = .714
g + l	Vertical line (2)	(Basic shape) circle vs. line, extends below, curv. segment (4)	4/6 = .667

Letter Pair	Common Features	Distinctive Features	% Distinctive
g + m	Circle (2)	Closed vs. open, tangent left vs. right, extends below, curv. segment, doubling (7)	7/9 = .777
g + n	Circle (2)	Closed vs. open, tangent left vs. right, extends below, curv. segment (6)	6/8 = .75
g + o	Circle, closed (4)	Tangent rt., extends below, curv. segment (3)	3/7 = .428
g + p	Circle, closed, extends below, tangent (8)	Tangent left vs. right, curved segment (3)	3/11= .272
g + q	Circle, closed, tangent, extends below, curved segment (10)	Curve to right vs. curve to left (2)	2/12= .167
g + r	Vertical line (2)	(Basic shape) circle vs. line, extends below, curv. segment bottom vs. top (5)	5/7 = .714
g + s	Circle (2)	Closed vs. open, tangent, extends below, curv. segment, alternation, open below (7)	7/9 = .777

Letter Pair	Common Features	Distinctive Features	% Distinctive
g + t	Vertical line (2)	(Basic shape) circle vs. line, extends below, curv. segment, crossbar (5)	5/7 = .714
g + u	Circle, tangent (4)	Open vs. closed, tangent rt vs. tangent left, extends below, curv. segment (6)	6/10 = .60
g + v	None	All	1.00
g + w	None	All	1.00
g + x	None	All	1.00
g + y	None	All	1.00
g + z	None	All	1.00
h + i	Vertical line (2)	(Basic shape) circle vs. line, dotted, extends above (4)	4/6 = .667
h + j	Vertical line (2)	(Basic shape) circle vs. line, dotted, extends above vs. below, curv. segment (6)	6/8 = .75
h + k	Vertical line, extends above (4)	(Basic shape) Circle vs. line, slanting segments (3)	3/7 = .428
h + l	Vertical line, extends above (4)	(Basic shape) circle vs. line (2)	2/6 = .333

Letter Pair	Common Features	Distinctive Features	% Distinctive
h + m	Circle, open at bottom, left tangent (6)	Doubling, extends above (2)	2/8 = .25
h + n	Circle, open, left tangent (6)	Extends above (1)	1/7 = .142
h + o	Circle (2)	Open vs. closed, tangent, extends above (4)	4/6 = .667
h + p	Circle, left tangent, extends (6)	Extends above vs. below, open vs. closed (4)	4/10= .40
h + q	Circle, tangent (4)	Open vs. closed, left tangent vs. right tangent, extends above vs. below, curv. segment (7)	7/11=.636
h + r	Vertical line (2)	(Basic shape) circle vs. line, extends above, curv. segment (4)	4/6 = .667
h + s	Circle, open (4)	Left tangent, extends above, open below vs. open right above and left below, alternation (6)	6/10 = .60
h + t	Vertical line, extends above (4)	(Basic shape) circle vs. line, crossbar, curv. segment (4)	4/8 = .50
h + u	Circle, open, tangent (6)	Open top vs. open bottom, tangent extends, tangent rt. vs. tangent left (5)	5/11= .454

Letter Pair	Common Features	Distinctive Features	% Distinctive
h + v	None	All	1.00
h + w	None	All	1.00
h + x	None	All	1.00
h + y	None	All	1.00
h + z	None	All	1.00
i + j	Vertical line, dotted (4)	Curved segment, extends below (2)	2/6 = .333
i + k	Vertical line (2)	Slanted segments, dotted (2)	2/4 = .50
i + l	Vertical line (2)	Dotted, extends above (2)	2/4= .50
i + m	Vertical line (2)	(Basic shape) circle vs. line, doubling, dotted (4)	4/6 = .667
i + n	Vertical line (2)	(Basic shape) circle vs. line, dotted (3)	3/5 = .60
i + o	None	All	1.00
i + p	Vertical line (2)	(Basic shape) circle vs. line, dotted, extends below (4)	4/6 = .667
i + q	Vertical line (2)	(Basic shape) circle vs. line, dotted, extends below, curv. segment (5)	5/7 = .714
i + r	Vertical line (2)	Dotted, curv. segment (2)	2/4 =.50

Letter Pair	Common Features	Distinctive Features	% Distinctive
i + s	None	All	1.00
i + t	Vertical line (2)	Dotted, crossbar, extends above (3)	3/5 = .60
i + u	Vertical line (2)	(Basic shape) circle vs. line, extends above	3/5 = .60
i + v	None	All	1.00
i + w	None	All	1.00
i + x	None	All	1.00
i + y	None	All	1.00
i + z	None	All	1.00
j + k	Vertical line (2)	Dotted, curv. segment, slanting segments, extends above vs. below (5)	5/7 =.714
j + l	Vertical line (2)	Dotted, curv. segment, extends above vs. below (4)	4/6 = .667
j + m	Vertical line (2)	(Basic shape) circle vs. line, doubling, dotted, curv. segment, extends below (6)	6/8 = .75
j + n	Vertical line (2)	(Basic shape) circle vs. line, dotted, curv. segment, extends below (5)	5/7 = .714

Letter Pair	Common Features	Distinctive Features	% Distinctive
j + o	None	All	1.00
j + p	Vertical line, extends below (4)	(Basic shape) circle vs. line, dotted, curv. segment (4)	4/8 = .50
j + q	Vertical line, extends below, curved segment (6)	(Basic shape) circle vs. line, dotted, curv. to left vs. curv. to right (5)	5/11= .454
j + r	Vertical line (2)	Dotted, curv. segment at top vs. at bottom, extends below (4)	4/6 = .667
j + s	None	All	1.00
j + t	Vertical line, curv. segment (4)	Dotted, crossbar, extends below, vs. above, curve to left vs. curve to right (6)	6/10= .60
j + u	Vertical line (2)	(Basic shape) circle vs. line, dotted, curv. segment, extends below (5)	5/7 = .714
j + v	None	All	1.00
j + w	None	All	1.00
j + x	None	All	1.00
j + y	None	All	1.00
j + z	None	All	1.00

Letter Pair	Common Features	Distinctive Features	% Distinctive
k + l	Vertical line, extends above (4)	Slanting segments (1)	1/5 = .20
k + m	Vertical line (2)	(Basic shape) circle vs. line, doubling, slanting segments, extends above (5)	5/7 = .714
k + n	Vertical line (2)	(Basic shape) circle vs. line, slanting segments, extends above (4)	4/6 = .667
k + o	None	All	1.00
k + p	Vertical line (2)	(Basic shape) circle vs. line, slanting segments, extends above vs. below, (5)	5/7 = .714
k + q	Vertical line (2)	(Basic shape) circle vs. line, slanting segments, extends above vs. below, curv. segment (6)	6/8 = .75
k + r	Vertical line (2)	Extends above, slanting segments, curv. segments	3/5 = .60
k + s	None	All	1.00
k + t	Vertical line (2)	Slanting segments, cross-bar, curv. segment (3)	3/5 = .60
k + u	Vertical line (2)	(Basic shape) circle vs. line, slanting segments, extends above (4)	4/6 = .667

Letter Pair	Common Features	Distinctive Features	% Distinctive
k + v	Slanting lines (2)	Vertical line, intersect at center vs. at bottom (3)	3/5 = .60
k + w	Slanting lines (2)	Vertical line, intersect at center vs. at bottom, doubling (4)	4/6 = .667
k + x	Slanting lines, intersect at center (4)	Vertical line, crossbar (2)	2/6 = .333
k + y	Slanting lines, (2)	Vertical line, extends below, intersect at center vs. at bottom (4)	4/6 = .667
k + z	Slanting lines (2)	Vertical line, horizontal lines (2)	2/4 = .50
l + m	Vertical line (2)	(Basic shape) line vs. circle, doubling, extends above (4)	4/6 = .667
l + n	Vertical line (2)	(Basic shape) line vs. circle, extends above (3)	3/5 = .60
l + o	None	All	1.00
l + p	Vertical line (2)	(Basic shape) line vs. circle, extends above vs. below (4)	4/6 = .667

Letter Pair	Common Features	Distinctive Features	% Distinctive
l + q	Vertical line (2)	(Basic shape) line vs. circle, extends above vs. below, curv. segment (5)	5/7 = .714
l + r	Vertical line (2)	Extends above, curv. segment (2)	2/4 = .50
l + s	None	All	1.00
l + t	Vertical line (2)	Extends above, crossbar, curv. segment (3)	3/5 = .60
l + u	Vertical line (2)	(Basic shape) circle vs. line, extends above (3)	3/5 = .60
l + v	None	All	1.00
l + w	None	All	1.00
l + x	None	All	1.00
l + y	None	All	1.00
l + z	None	All	1.00
m + n	Circle, open bottom, left tangent (6)	Doubling (1)	1/7 = .142
m + o	Circle, (2)	Open vs. closed, doubling, tangent (4)	4/6 = .667
m + p	Circle, left tangent (4)	Open vs. closed, doubling, extends below (4)	4/8 = .50
m + q	Circle, tangent (4)	Open vs. closed, doubling, tangent rt. vs. left, , extends below, curv. seg.	7/11= .636

Letter Pair	Common Features	Distinctive Features	% Distinctive
m + r	Vertical line (2)	(Basic shape) circle vs. line, doubling, curv. segment (4)	4/6 = .667
m + s	Circle, open (4)	Open bottom vs. open right, left, doubling, tangent, alternation (6)	6/10= .60
m + t	Vertical line (2)	(Basic shape) circle vs. line, doubling, curv. segment, crossbar (5)	5/7 = .714
m + u	Circle, open, tangent (6)	Tangent on right vs. on left, doubling, open top vs. open bottom (5)	5/11= .454
m + v	None	All	1.00
m + w	Doubling (2)	(Basic shape) circle vs. line, slanting vs. vertical (4)	4/6 = .667
m + x	None	All	1.00
m + y	None	All	1.00
m + z	None	All	1.00
n + o	Circle (2)	Open vs. closed, tangent (3)	3/5 = .60
n + p	Circle, left tangent (4)	Open vs. closed, tangent extends below (3)	3/7 = .428

Letter Pair	Common Features	Distinctive Features	% Distinctive
n + q	Circle, tangent (4)	Open vs. closed, tangent left vs. tangent rt., extends below, curv. segment (6)	6/10 = .60
n + r	Vertical line (2)	(Basic shape) circle vs. line, curv. segment (3)	3/5 = .60
n + s	Circle, open (4)	Tangent, open at bottom vs. open at left-below and rt.-above, alternation (5)	5/9 =.555
n + t	Vertical line (2)	(Basic shape) circle vs. line, crossbar, extends above, curv. segment(5)	5/7 =.714
n + u	Circle, tangent, open (6)	Open at top vs. open at bottom, tangent left vs. tangent right (4)	4/10 =.40
n + v	None	All	1.00
n + w	None	All	1.00
n + x	None	All	1.00
n + y	None	All	1.00
n + z	None	All	1.00
o + p	Circle, closed (4)	Left tangent, extends below (2)	2/6 = .333
o + q	Circle, closed (4)	Right tangent, extends below, curved segment (3)	3/7 =.428
o + r	None	All	1.00

Letter Pair	Common Features	Distinctive Features	% Distinctive
o + s	Circle (2)	Closed vs. open on rt. above, left below, alternation (4)	4/6 = .667
o + t	None	All	1.00
o + u	Circle (2)	Closed vs. open at top, tangent on right (3)	3/5 = .60
o + v	None	All	1.00
o + w	None	All	1.00
o + x	None	All	1.00
o + y	None	All	1.00
o + z	None	All	1.00
p + q	Circle, tangent, extends below (6)	Left tangent vs. right tangent, curv. segment (3)	3/9 = .333
p + r	Vertical line (2)	(Basic shape) circle vs. line, extends below, curv. segment (4)	4/6 = .667
p + s	Circle (2)	Open vs. closed, alternation, tangent, extends below (5)	5/7 = .714
p + t	Vertical line (2)	(Basic shape) circle vs. line, extends below vs. above, crossbar, curv. segment (6)	6/8 = .75

Letter Pair	Common Features	Distinctive Features	% Distinctive
p + u	Circle, tangent (4)	Open vs. closed, left tangent vs. right tangent, extends below (5)	5/9 = .555
p + v	None	All	1.00
p + w	None	All	1.00
p + x	None	All	1.00
p + y	Extends below (2)	(Basic shape) circle vs. line, slanting segments, vs. vertical line (4)	4/6 = .667
p + z	None	All	1.00
q + r	Vertical line	(Basic shape) circle vs. line, extends below, curv. segment bottom vs. top (5)	5/7=.714
q + s	Circle (2)	Open vs. closed, tangent, extends below, curv. segment, alternation (6)	6/8 = .75
q + t	Vertical line (2)	(Basic shape) circle vs. line, crossbar, extends below vs. above, curv. segment bottom vs. top (7)	7/9 = .777
q + u	Circle, tangent on right (4)	Open vs. closed, extends below, curv. segment (4)	4/8 = .50

Letter Pair	Common Features	Distinctive Features	% Distinctive
q + v	None	All	1.00
q + w	None	All	1.00
q + x	None	All	1.00
q + y	Extends below (2)	(Basic shape) circle vs. line, curv. segment, slanting segments vs. vertical (5)	5/7 = .714
q + z	None	All	1.00
r + s	None	All	1.00
r + t	Vertical line (2)	Curv. segment top vs. bottom, extends above, crossbar (4)	4/6 = .667
r + u	Vertical line (2)	(Basic shape) circle vs. line, curv. segment (3)	3/5 = .60
r + v	None	All	1.00
r + w	None	All	1.00
r + x	None	All	1.00
r + y	None	All	1.00
r + z	None	All	1.00
s + t	None	All	1.00
s + u	Circle, open (4)	Open top vs. open left and right, tangent, alternation (5)	5/9 = .555

Letter Pair	Common Features	Distinctive Features	%Distinctive
s + v	None	All	1.00
s + w	None	All	1.00
s + x	None	All	1.00
s + y	None	All	1.00
s + z	Alternation (2)	Circle vs. line (basic shape), open top right vs. top left (4)	4/6 = .667
t + u	Vertical line (2)	(Basic shape), circle vs. line, crossbar, curv. segment, extends above (5)	5/7 = .714
t + v	None	All	1.00
t + w	None	All	1.00
t + x	Center intersection, crossbar (4)	Slanting lines vs. vertical, extends above, curv. segment (4)	4/8 = .50
t + y	None	All	1.00
t + z	Horizontal line (2)	Extends above, slanting segment, curv. segment, alternation	4/6 = .667
u + v	None	All	1.00
u + w	None	All	1.00
u + x	None	All	1.00
u + y	None	All	1.00
u + z	None	All	1.00

Letter Pair	Common Features	Distinctive Features	% Distinctive
v + w	Slanting lines, bottom intersection (4)	Doubling (1)	1/4 = .25
v + x	Slanting lines (2)	Crossbar, center intersection vs. bottom intersection (3)	3/5 = .60
v + y	Slanting lines, bottom intersection (4)	Extends below (1)	1/5 = .20
v + z	Slanting lines (2)	Horizontal vs. vertical alternation (2)	2/4 = .50
w + x	Slanting lines (2)	Doubling, crossbar (2)	2/4 = .50
w + y	Slanting lines (2)	Doubling, extends below (2)	2/4 = .50
w + z	Slanting lines (2)	Horizontal alternation vs. vertical, doubling (3)	3/5 = .60
x + y	Slanting lines (2)	Crossbar, extends below (2)	2/4 = .50
x + z	Slanting lines (2)	Crossbar, horizontal vs. slanting lines (3)	3/5 = .60
y + z	Slanting lines (2)	Horizontal vs. slanting lines, extends below (3)	3/5 = .60